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その他（別言語等）のタイトル	圧力センサーによる湾状地形における長波の測定(1)
著者(英語)	Kuniaki Abe
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# Long wave measurements at bay-shaped coasts using a pressure gauge (I)

Kuniaki ABE

Niigata Junior College, The Nippon Dental University,  
Hamauracho 1-8, Niigata, 951-8580, JAPAN

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## Abstract

Long wave measurements with a pressure gauge were conducted at bay-shaped coasts in Kouzushima Island and Izu peninsula facing to northwest Pacific Ocean. The sampling time is 10 sec and the total measuring time is 2 hours for one place. The time histories were decomposed into spectra and the predominant periods were determined. As the result predominant periods of 6 minutes were found at a head of Kouzushima port and at Koina in a bay of the Izu Peninsula. They are explained from a formula of resonance. In Kouzushima small tsunami on July 1, 2001 the predominant periods were observed displacing by small amounts in comparison with the observed periods.

## 1. Introduction

Omori (1901) discovered sea level oscillations of the same period of 7.1-7.3 minutes for various tsunamis observed at Ayukawa tide station in Honshu, Japan. This fact led Honda et al. (1902) to measure secondary undulations (seiche) at various bays along Japanese coasts in a daily state. They summarized the result as predominant periods observed in the daily oscillations. Nakano and Unoki (1962) statistically studied it observed in tide stations and described that the period is not defined

definitely but is variable with a wide range. After that spectral analysis was developed, and Takahashi and Aida (1963) pointed out that the same predominant periods were observed at a fixed station in spite of different tsunamis.

From the opposite viewpoint it is suggested that there is a possibility to reveal tsunami source mechanism. Miller (1972) noticed the spectral ratio between two different tsunamis, excluding an effect of station response, and defined color of tsunami. Baptista *et al.* (1992) interpreted observed spectra as multiplied ones including information of the source. Rabinovich (1997) applied the method to some tsunamis and separated the source spectra from the observed ones.

As for the measuring instruments Honda *et al.* (1902) used a portable mercury pressure-gauge instead of tide gage installed at tide station. Aida *et al.* (1972) measured sea level oscillation at Onagawa bay using a mercurial marigraph. A pressure gauge is a modern instrument for measuring sea level (W.J.Emery and R.E. Thomson, 1997). The pressure gauge of semiconductor, made for monitoring the underground water level and improved to use in salt water, is used to measure long wave, of which response was studied by Abe (2001).

## 2. Measurements

The measurements were carried out on July 26-27, 2000 at Kouzushima port in Kouzushima Island and Koina in the Izu Peninsula, Japan, as shown in **Figure 1**. The weather conditions were rainy in the morning of July 26, cloudy in the afternoon, and fine in all day on July 27. In both the days wind was not noticed. The data were taken for four points in Kouzushima port and one point in Koina, the Izu Peninsula with time interval of 10 s for total sampling time of 2 hours (**Figure 2**). The stored data were processed with a microcomputer and the time series under Hanning window was decomposed into spectra on Goertzel method. The amplitude spectra were filtered with running average and shown in **Figure 3**. In the analysis the response was checked at a laboratory experiment. The result is shown in Appendix.

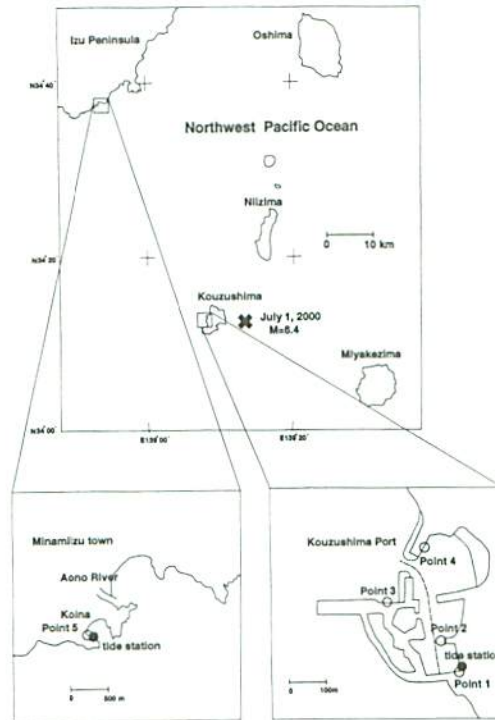


Figure 1 Location of observation points. Cross is an epicenter of the earthquake of 1 July 2000.

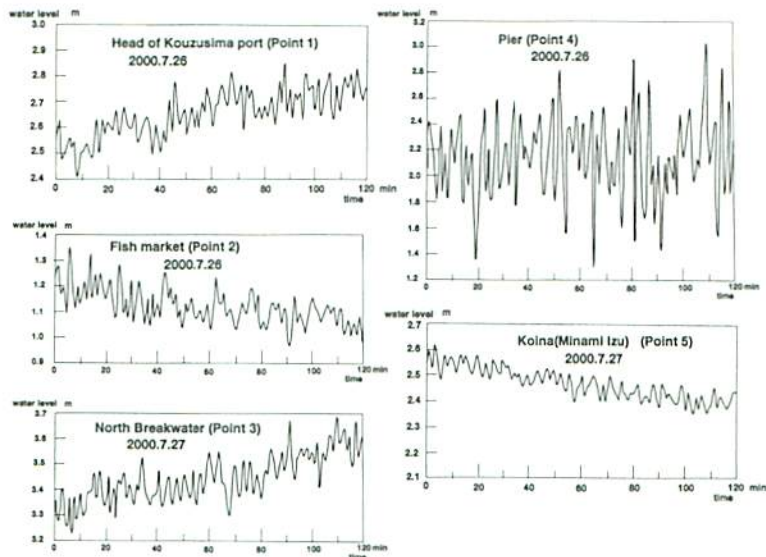


Figure 2 Time histories of sea levels observed. The observation points are shown in Figure 1.

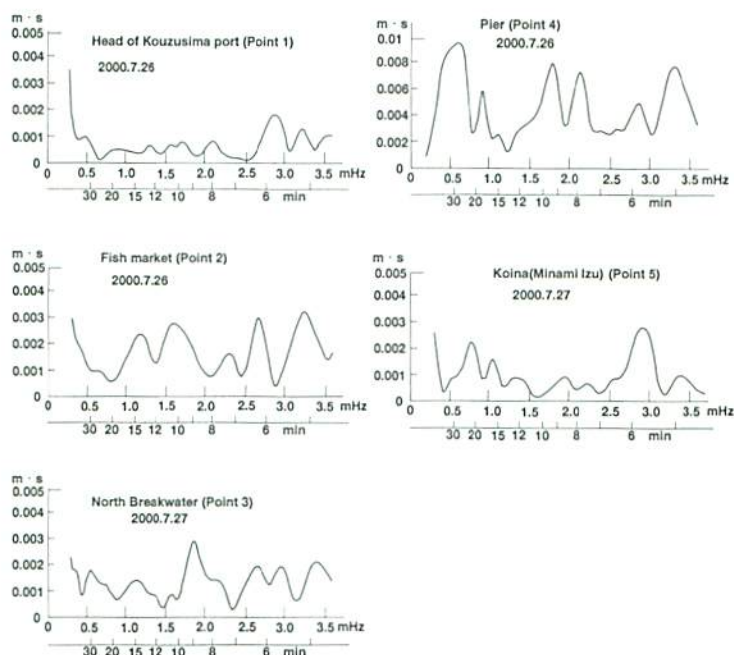


Figure 3 Amplitude spectra of the time histories shown in Figure 2.

### 3. Predominant periods

We notice the peak frequency or period as the most predominant frequency or period in the spectra. At a head of Kouzushima port (Point 1) it is 2.9 mHz or 5.7 min. It is displaced into 2.7 mHz or 6.2 min at a fish market (Point 2) between head and mouth. At a pier outside of the port (Point 4) it is 0.6 mHz or 28 min. It is long in the period in comparing with the former two. At a north breakwater nearest to the mouth (Point 3) it is 1.9 mHz or 8.6 min, which is the intermediate value. It is interesting that the same period component also predominated at the pier, which suggests that the wave cover these two places. At Koina (Point 5) it is 2.9 mHz or 5.7 min, which is the same as the head of Kouzushima port.

The predominant periods observed at Kouzushima port were plotted along a center-line of the port, which is shown in Figure 4. It is clarified that long wave component



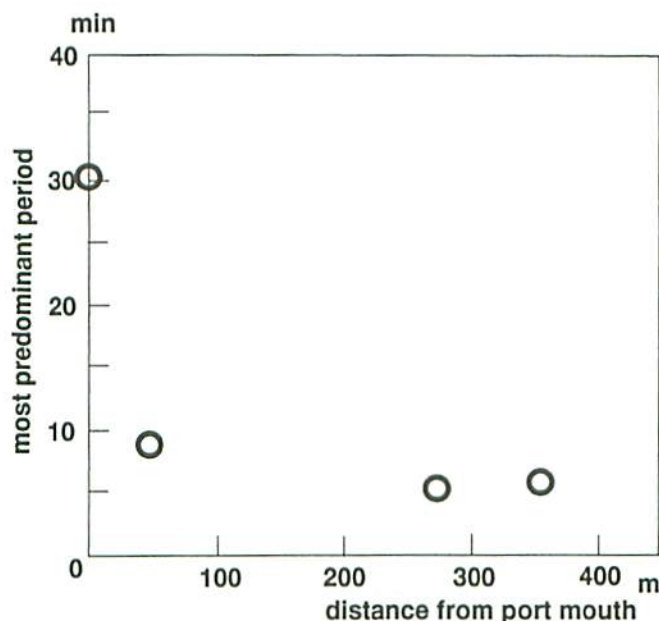


Figure 4 Dependence of the most predominant periods on distance from mouth of Kouzushima port. The distance is taken along a curve shown in Figure 1.

of 28 minutes observed outside of the port does not penetrate into the port and short ones of 6–9 minutes in period predominated inside the port. This fact suggests that the breakwater at the mouth contributes to a stop of the wave of 28 min from propagating into the port. The short one is possibly excited within the port. At two points nearest to the head almost the same period of 6 min as the most predominant ones are probably the same wave components. Moreover, the period differs from 9 minutes, observed at Point 3 near to the mouth, by 3 minutes. These facts suggest that the wave of 6 minutes is amplified at the head. Thus, the period component of 6 minutes is explained from Merian's resonance formula, which is expressed as

$$T_0 = 4L / \sqrt{gh}.$$

In this formula  $T_0$ ,  $L$ ,  $g$  and  $h$  are period, length of the port, acceleration of gravity and depth of the port, respectively. When we assume that  $L$ ,  $g$  and  $h$  are 330 m, 9.8 m/s<sup>2</sup> and 1.5 m, we obtain 5.7 minutes, coinciding to the observed value.

At Koina we assume the same formula as one at Kouzushima port. We obtain 6.0 minutes as a resonance period for  $L$  of 320 m and  $h$  of 1.3 m. It is a good approxima-

tion of 5.7 minutes observed. It is concluded that we observed typical resonance periods for Kouzushima port and Koina.

#### 4. Kouzushima tsunami on July 1, 2000

An seismic activity around Kouzushima and Miyakezima islands continued from June 29 to August 31, 2000. On July 1 in the period a big earthquake of magnitude 6.4 generated accompanying a tsunami and the tsunami was observed at tide stations of Kouzushima port, nearest to Point 1, and Minami Izu, nearest to Point 5. The records were transferred into the spectra as shown in Figure 5. The method is the same as former one. The total sampling time of 2 hours include the most part of the

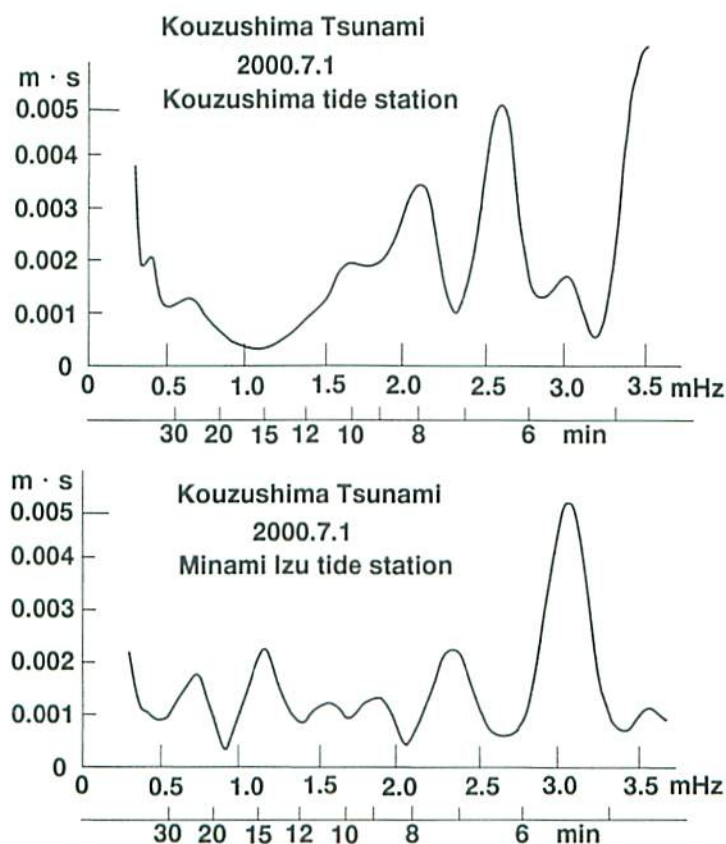


Figure 5 Amplitude spectra of Kouzushima tsunami observed at tide stations, Kouzushima (a) and Minami Izu (b).

tsunami. The result shows the most predominant frequency of 3.5 mHz or period of 4.8 min at tide station located in the head of Kouzushima port. This period is small by 0.9 min in comparison with the most predominant period observed at the daily state. On the other hand the most predominant frequency of 2.7 mHz or period of 6.2 min was observed at tide station located in Koina, Izu peninsula. This value is larger than that of the most predominant period observed at the daily state by 0.5 min. Thus, the predominant periods of the Kouzushima tsunami were observed displacing from those at daily states by 0.5-0.9 min.

Abe (2000) carried out a numerical experiment of this tsunami. He assumed the fault length of 15 km in the experiment. When we assume an average depth of 200 m at the source area, we obtain a period of the tsunami to be 5.6 minutes. Nevertheless the rough estimation, it is comparable to the predominant periods of 4.8-6.2 minutes observed. It is concluded that the period component excited by the earthquake had a value nearest to the predominant periods observed in daily states. In the discussion it is assumed that the tide gauge response is flat for the period range.

## 5. Discussion

According to Nakano and Unoki (1972) the predominant period is not definite but variable. But a large difference of the most predominant period between the one outside of the port and the one inside of the port shows a difference of wave excitation. The difference corresponds to a separation of the port from the outer sea. The closed structure of the port is effective to excite a natural oscillation of the port. It is considered that degree of the variability depends on the structure. The structure prefers to a definite predominant period.

## 6. Conclusion

Long wave oscillation was measured at Kouzushima port, Kouzushima Island and at Koina, the Izu Peninsula. From the spectra it is revealed that wave with 6 minutes predominated in the most quantity at a head of the port and Koina. Since both the periods almost coincide with the resonance periods estimated from a resonance for-



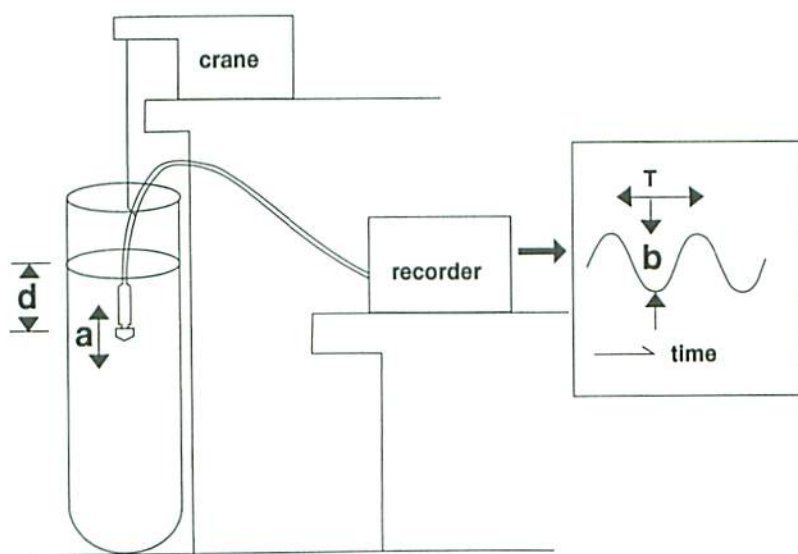
mula, it is concluded that we observed natural oscillations in the port and the bay. It is verified from tide gauge records that the most predominant periods observed in Kouzushima tsunami on July 7, 2000 displaced by a small amount at the port and Koina. The fact suggests that wave component excited by the earthquake had a value nearest to the predominant periods observed at Kouzushima port and Koina in a daily state.

### Acknowledgement

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### Appendix

Frequency response of the pressure gauge was measured at a laboratory. The block diagram is shown in **Figure A1**. A motor crane with the period  $T$  of 7.6-7.8 s drove the gauge. The dynamic response is expressed by amplitude ratio of recorded one  $b$  to the driving displacement  $a$ . Especially the depth dependence was plotted in depth-



**Figure A1** Block diagram of the calibration.

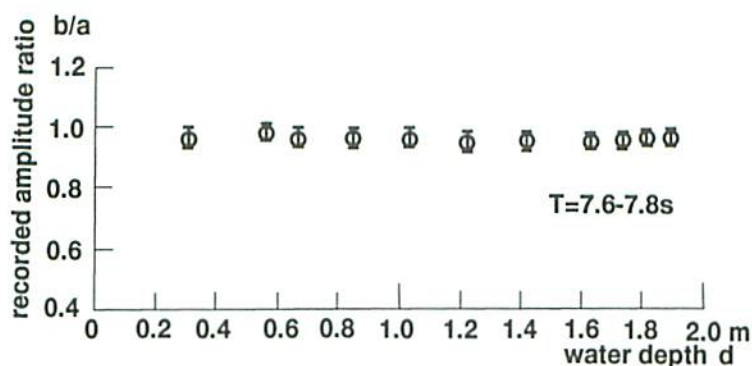


Figure A2 Dependence of the response  $b/a$  on water depth  $d$ . The period  $T$  is fixed to 7.6-7.8 s.

amplitude ratio diagram as shown in Figure A2. It is flat up to 2 m in depth  $d$  and the average is 0.97-0.98. Error bars in the figure are attributed to a discrete sampling of the amplitude. When the error is taken into consideration, the response is almost perfect. Moreover, the period of 7.6 s is short enough to compare that of long wave studied here. Abe (2001) checked the static response to the depth and the reproducibility of water level was proved. Summarizing these facts and a treatment of period longer than 5 minutes we can conclude that the reproducibility are reliable.

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